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SHOCK INTENSITY AND SIGNALED AVOIDANCE RESPONDING

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Five rats were submitted to a signaled free-operant avoidance contingency. Throughout the experiment, shock intensity was varied from 0.1 to 8.0 mA, with shock duration constant at 200 milleseconds. Results indicate: (a) an all-or-none effect of shock intensity on response and shock rates, on percentage of shocks avoided, and on frequency of occurrence of responding during the preshock stimulus; and (b) no systematic effect of shock intensity on stimulus control, measured either by the percentage of stimulus presentations accompanied by a response or by the percentage of responses that occurred during those preshock stimuli. Such results indicate that for each subject there is a minimum shock intensity necessary to establish and maintain avoidance responding; intensities higher than this minimum value have little or no effect on responding (with an upper limit for those strong intensities with a general disruptive effect on behavior).

Key words: signaled free-operant avoidance, shock intensity, bar press, rats

In the signaled free-operant avoidance procedure (Sidman, 1955), a given stimulus is presented at a fixed time interval before a scheduled shock. Responses in the presence of that stimulus terminate it and postpone the shock; responses before the onset of the stimulus postpone both its presentation and the scheduled shock. In the absence of responses, a shock will terminate the preshock stimulus and initiate a new trial (Sidman, 1955) or the preshock stimulus may be removed only by the next response (Ulrich, Holz, & Azrin, 1964). In both pigeons and rats, stimulus control of responding occurs when the signaled free-operant avoidance procedure is used, with frequent responding during the preshock stimulus and a lower frequency in its absence (see Alves de Moraes & Todorov, 1977).

In spite of a considerable number of studies found in the literature (see Hineline, 1977), the effect of shock intensity on response rate maintained by such procedures has not been studied. The purpose of the present investigation was to verify the effect of different intensities of electric shock on response rates and on stimulus control of responding in a signaled free-operant avoidance contingency.

METHOD

Subjects

Five adult male Wistar rats served; they were approximately 130 days old and all were experimentally naive. Subjects were housed individually, with free access to food and water in their home cages.

Apparatus

A standard experimental chamber for rats (Grason-Stadler Model 1111-L) with two response bars was used. Bars were 5.0 cm wide, were placed 7.2 cm apart, and were located 9.4 cm from the floor. The right bar

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was modified and had a stainless steel extension affixed to it, measuring 5.8 cm (length) by 5.0 cm (width), making a 90° angle with the bar. The bottom end of this extension was slightly hollow, making a kind of stair. A minimum force of 0.01 N operated the response bar and produced auditory feedback by operating a relay. The left bar was fixed and inoperative throughout the experiment. A translucent jeweled red light (2 W, 12.6 V) was located above and to the right of the response bar; a houselight (2 W, 12.6 V) was located on the ceiling and to the left side of the frontal wall. A Grason-Stadler Model 700 shock source, with scrambler, delivered shocks to grids, bars, and three walls (except the clear plastic door). Shock intensity was measured before each experimental session by using a 10 K-ohm resistance in place of the rats. Standard electromechanical circuits housed in an adjacent room controlled events.

Procedure

Sidman's (1955) signaled free-operant avoidance procedure was utilized. The preshock stimulus (S_1) was the simultaneous onset of the red light above the response bar and of the houselight. Responses or shocks turned off both lights and darkened the chamber. When the chamber was darkened, responses postponed the onset of the lights and consequently of the electric shock. Duration of electric shocks (S_2) was 200 ms; shocks were not terminated by responses. Shaping of the bar-press response was conducted following the general procedure described by Ferrari, Todorov, and Graeff (1973), adapted for rats. Time parameters, the response to preshock stimulus (RS_1) interval and the S_1 to shock (S_1S_2) interval, were gradually increased from 5 to 10 s each (so the RS_2 and the S_2S_2 intervals were equal to 20 s at the end of the shaping session). Shock intensity was 1.3 mA for four rats (R2, R52, R68, and R69) and 0.8 mA for Subject R1 during shaping.

In different experimental conditions, shock intensity was manipulated within the range of 0.1 to 8.0 mA. Table 1 shows intensities, order of presentation, and number of sessions per condition for each subject. Experimental conditions were changed when, after a minimum of 14 sessions, (a) cumulative records indicated, through visual inspection, regularities in responding in five consecutive sessions; (b) the difference between response rates in any of the five sessions was less than 10% of the average; *and* (c) no ascending or descending trends were observed in response rates in those five sessions. Whenever this triple criterion was not reached, changes in condition occurred after 70 consecutive sessions with a given shock intensity. On those conditions in which subjects stopped responding before 14 sessions, the change in condition occurred after three consecutive sessions without responses. Daily 90-min sessions were conducted for Rats R1, R2, R52, and R69; session duration was 150 min for Rat 68.

RESULTS

Figure 1 shows how response rates changed with variations in shock intensity. Each point refers to the average response rate (resp/min) in the last five sessions of a given condition. The broken horizontal line represents the minimum response rate required to avoid all scheduled shocks (Pomerleau, 1970). Shock intensity had an all-or-none effect on response rates. Responding was absent or near zero with low intensities (below 0.8 mA), and response rates were above the minimum required rate with shock intensities of 1.0 mA and higher. Increases in shock intensity above 1.0 mA did not systematically affect response rate. It should be noticed that some points referring to the first exposure to a given shock intensity show lower response rates than those observed on replications (Rat R2, with 1.0 mA; Rats R2 and R69, with 1.3 mA; Rat R1, with 1.6 mA), but almost the same response rates were observed in the first determinations and in replications with 1.3 mA and 2.0 mA for Rat R52.

The all-or-none effect can be seen also on the percentage of shocks avoided (Figure 2)

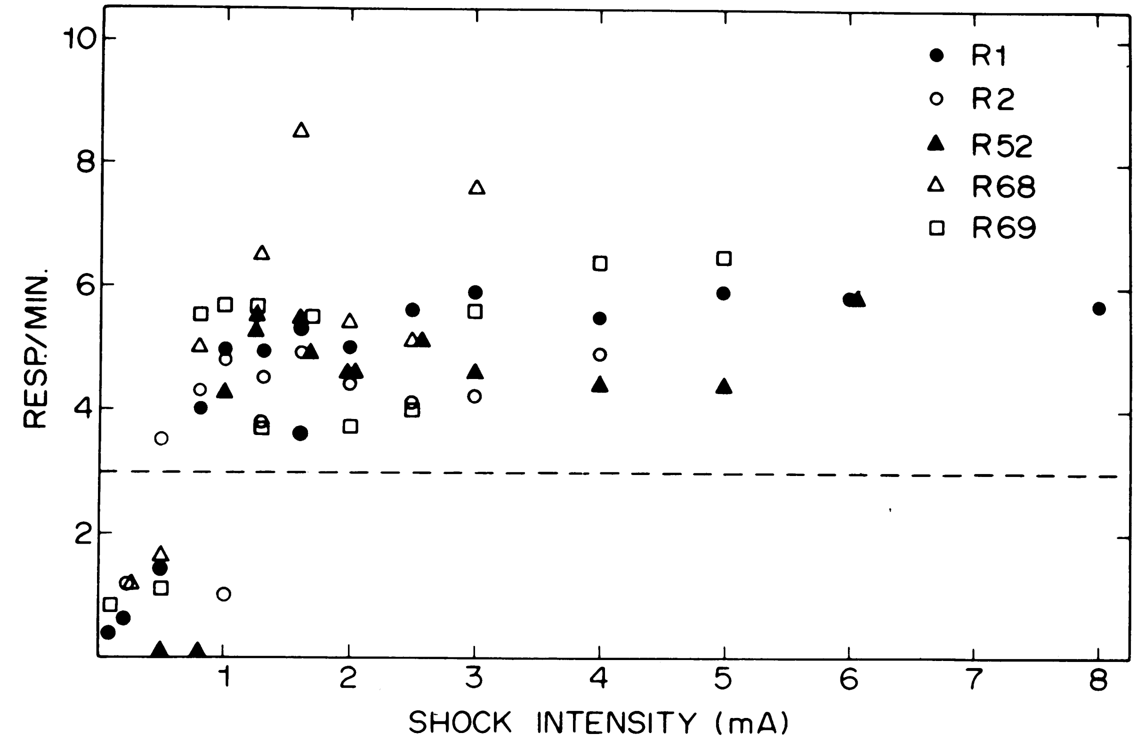

Fig. 1. Response rates (resp/min) as a function of shock intensity (mA). Symbols identify data from different subjects.

and on rate of shocks delivered (Figure 3). Both measures show an abrupt change with shock intensities between 0.8 and 1.0 mA, and no systematic effects of increases in shock intensity above 1.0 mA.

Figure 4 shows the effects of changes in shock intensity on stimulus control. Left graphs show how the percentage of stimulus presentations that were accompanied by a response (number of stimulus presentations accompanied by a response divided by total number of stimulus presentations) changed with variations in shock intensity. The all-or-none effect is observed again around 0.8 to 1.0 mA. For all five rats and shock intensities of 1.0 and higher, responses terminated the preshock stimulus in at least 75% of the occasions; increases in shock intensity above 1.0 mA had no systematic effect on this relative measure.

The graphs on the right side of Figure 4 show the percentage of responses that occurred during the preshock stimulus (number of responses in the presence of the stimulus divided by total number of responses) for all values of shock intensity used. The solid horizontal line (50%) shows the percentage of responses that would occur during the preshock stimulus if responding were equally probable in the presence and absence of the preshock stimulus. When post-shock responses or short interresponse times are predominant, most responses occur before the onset of the preshock stimulus, and deviations from indifference (50%) appear as lines dropping from the horizontal line. When relatively few responses occur before the stimulus onset, the degree of stimulus control is shown by vertical lines rising from indifference. Increases in shock intensity above 1.0 mA had no systematic effect on this measure of stimulus control.

The number of sessions needed to reach the stability criterion also points to a critical region around 0.8 to 1.0 mA. Maximum number of sessions per condition occurred for shock intensities in those proximities (Table 1).

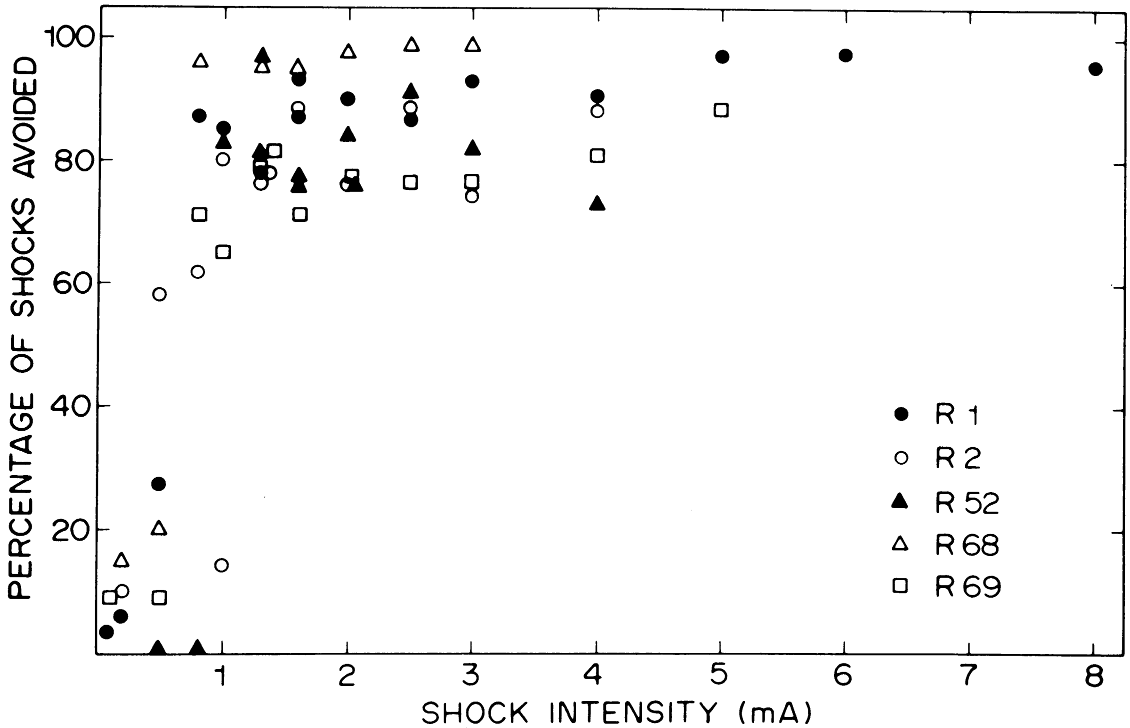

Fig. 2. Percentage of shocks avoided (shocks scheduled minus shocks delivered, divided by the maximum number of shocks that could be scheduled) as a function of shock intensity (mA). Symbols identify data from different subjects.

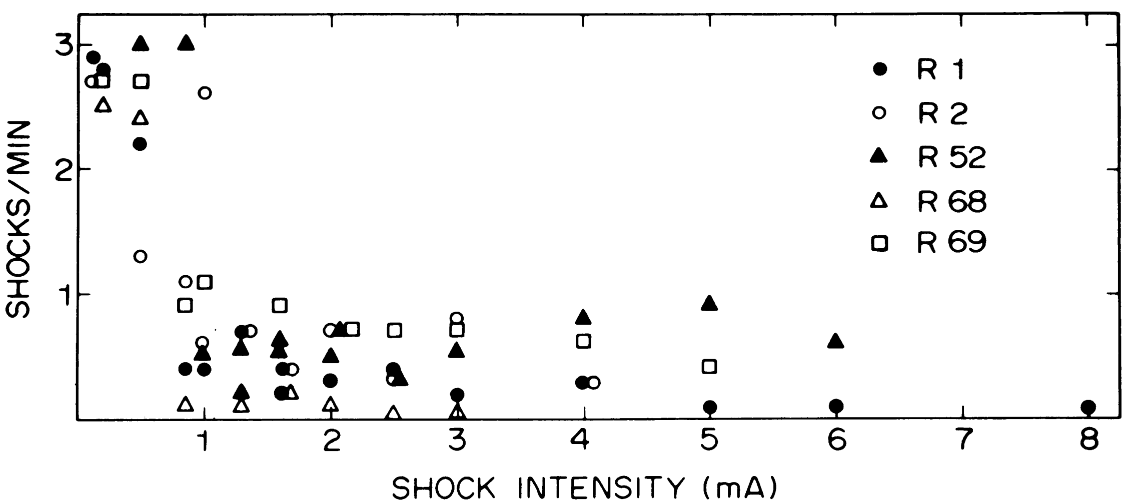

Fig. 3. Rates of shocks delivered (shocks/min) as a function of shock intensity. Symbols identify data from different subjects.

DISCUSSION

Present results show an all-or-none effect of shock intensity on performance maintained by a signaled free-operant avoidance procedure. When shock intensity was increased to values near 1.0 mA, abrupt increases were observed in response rate, in rate of shocks avoided, and in percentage of preshock stimuli accompanied by a response,

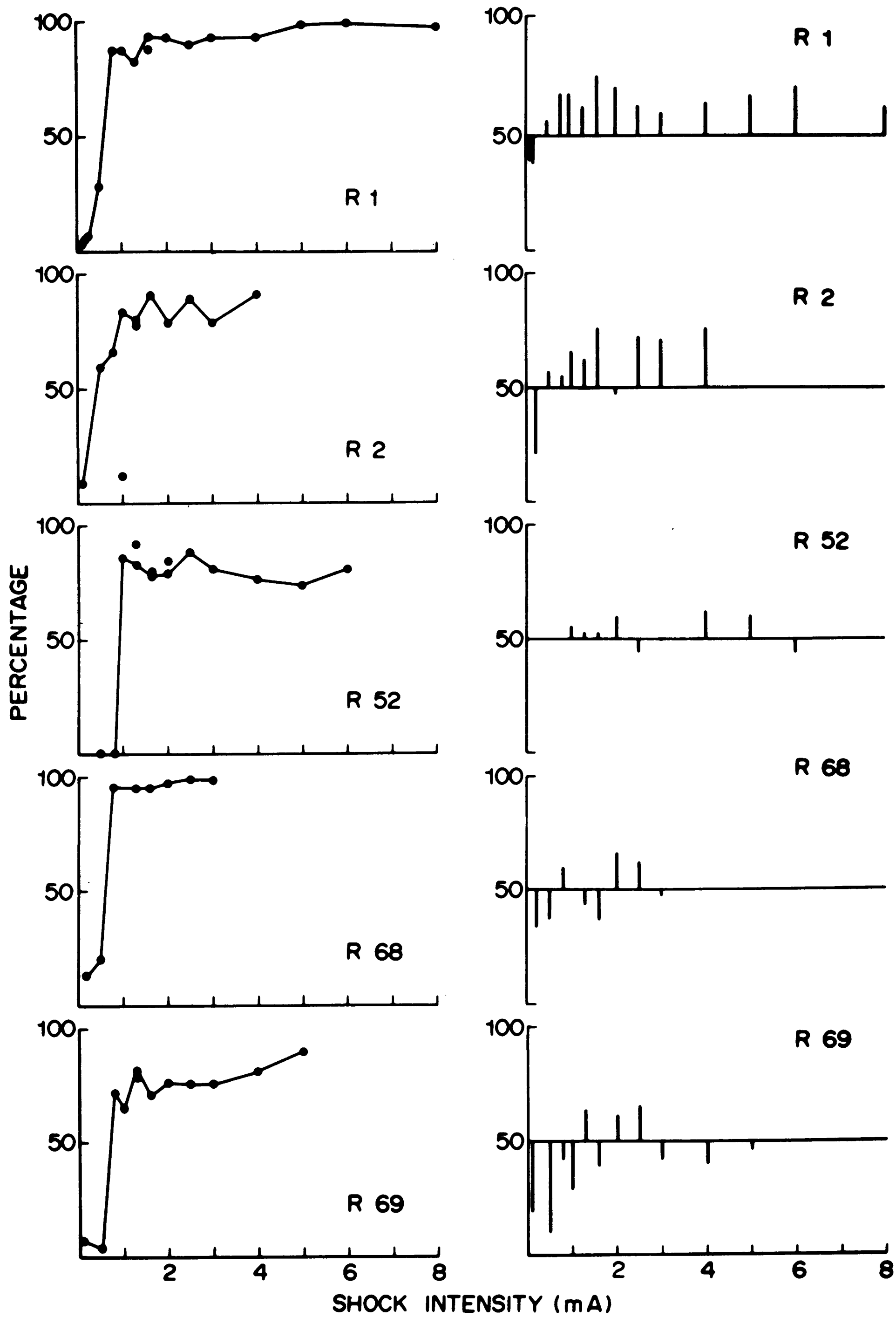

Fig. 4. Left graphs show the percentage of stimulus presentations that were accompanied by a response as a function of shock intensity (mA). Right graphs show the percentage of responses that occurred during the preshock stimulus as a function of shock intensity (mA).

Table 1

Shock intensity, condition order, number of sessions, sum of responses, preshock stimulus presentations, and shocks delivered, in the last five sessions in each experimental condition.

Shock Intensity (mA)	*Condition Order*	*No. of Sessions*	*Responses* Total	*Responses* During RS_1	*Responses* During S_1S_2	*Preshock Stimuli*	*Shocks*
Subject R1							
0.1	12	30	164	101	63	1367	1304
0.2	10	14	256	162	94	1371	1279
0.5	3	70	715	312	403	1420	1017
0.8	1	15	1803	550	1253	1427	174
1.0	8	28	2184	708	1476	1681	205
1.3	4	21	2212	841	1371	1661	290
1.6	2	17	1635	398	1237	1409	172
1.6	11	14	2452	799	1653	1746	93
2.0	6	19	2238	653	1585	1712	137
2.5	5	14	2504	926	1578	1746	168
3.0	9	14	2613	1044	1569	1671	102
4.0	7	14	2483	890	1591	1716	125
5.0	13	16	2670	875	1795	1827	32
6.0	14	21	2594	760	1834	1859	25
8.0	15	16	2577	979	1598	1641	43
Subject R2							
0.2	9	17	554	436	118	1366	1215
0.5	11	14	1587	710	877	1454	577
0.8	6	70	1930	919	1011	1531	520
1.0	4	70	432	270	162	1338	1176
1.0	10	15	2110	731	1379	1653	274
1.3	1	59	2028	767	1261	1583	322
1.3	12	14	1737	674	1063	1366	303
1.6	7	18	2203	543	1660	1823	163
2.0	3	17	1987	1053	934	1262	328
2.5	2	16	1862	528	1334	1492	158
3.0	5	14	1878	549	1329	1677	348
4.0	8	16	2197	530	1667	1821	154
Subject R68							
0.2	7	57	901	601	300	2216	1916
0.5	4	70	1214	666	448	2250	1802
0.8	2	47	3775	1558	2217	2317	100
1.3	1	33	4899	2796	2103	2204	101
1.6	5	27	6744	4287	2457	2593	136
2.0	8	14	4042	1414	2628	2676	48
2.5	3	19	3847	1508	2339	2355	16
3.0	6	22	5679	2999	2650	2680	30
Subject R52							
0.5	9	5	0	0	0	1350	1350
0.8	6	7	2	2	0	1350	1350
1.0	4	43	1945	871	1074	1306	232
1.3	1	25	2374	1168	1206	1471	265
1.3	12	14	2489	1373	1116	1216	100
1.6	7	34	2199	1063	1136	1463	327
1.6	13	15	2471	1332	1139	1443	304
2.0	3	16	2070	844	1226	1548	322
2.0	11	17	2092	1098	994	1213	219
2.5	2	14	2297	1301	996	1124	128
3.0	5	14	2068	1047	1021	1260	239
4.0	8	14	1978	745	1233	1605	372
5.0	10	14	1974	816	1158	1156	398
6.0	14	14	2631	1482	1149	1432	283
Subject R69							
0.1	10	29	335	238	97	1330	1233
0.5	4	70	493	444	49	1309	1260
0.8	7	49	2475	1446	1029	1426	397
1.0	8	33	3077	1662	894	1374	480
1.3	1	14	1642	606	1036	1320	284
1.3	11	14	2522	1319	1203	1473	270
1.6	5	30	2503	1524	979	1372	393
2.0	3	22	1691	671	1020	1329	309
2.5	2	20	1807	806	1001	1319	318
3.0	6	22	2502	1446	1056	1386	330
4.0	9	10	2878	1736	1142	1407	265
5.0	12	16	2935	1578	1357	1518	161

with abrupt decreases in shocks delivered. Further increases in shock intensity showed no systematic effects on those variables. Shock intensities below 0.8 mA were not sufficient to maintain avoidance responding.

Such results indicate that for each subject there is a minimum shock intensity necessary to establish and maintain avoidance responding; intensities higher than this minimum value have little or no effect on responding (with an upper limit for those strong intensities with a general disruptive effect on behavior).

Present conclusions diverge from those found in the literature on avoidance. Generally, response rate is described as a direct, negatively accelerated, monotonic function of shock intensity (Boren, Sidman, & Herrnstein, 1959; D'Amato, Fazzaro, & Etkin, 1967; Klein & Rilling, 1972; Riess, 1970). A close examination of such reported data, however, indicates the same all-or-none effect found in the present results. Two studies present apparently stronger evidence against an all-or-none effect. Powell (1970) used groups of subjects and only two intensities of shock, 1.0 and 2.0 mA, and concluded that response rates increase with increases in shock intensity. Two major objections may be raised concerning Powell's conclusion: Only two points are insufficient evidence for any strong conclusion, and the 1.0-mA intensity is within the range at which abrupt changes were observed in the present experiment. Leander (1973) combined different values of shock intensity and duration and concluded that response rate increases with increases in the product of shock intensity and shock duration. However, Leander used shock intensities ranging from 1.0 to 4.0 mA (with intermediate values increasing by steps of 0.5 mA) and three shock durations of 0.30, 0.50, and 0.75 ms. When the product of shock parameters was 0.30, performance was poor. When shock intensity varied but shock duration was constant at 0.50 or 0.75 ms, Powell's results show no effect of shock intensity on response rates.

More evidence for an all-or-none effect of shock intensity on response rate is reported by Harsh and Badia (1975). Rats could either receive unsignaled shocks or they could respond and change the situation so that shocks were preceded by a stimulus. With low shock intensities, subjects received most shocks in the unsignaled situation. When shock intensity was raised to 0.6 mA, the percentage of time spent in the signaled situation increased abruptly. Further increases up to 4.0 mA had no systematic effect on behavior.

The insensitivity of avoidance responding to changes in shock intensity above a critical value seems to parallel the insensitivity of responding in single schedules of reinforcement to changes in reinforcement magnitude (see Catania, 1963, 1966). There is no information on concurrent avoidance responding in which alternatives differ in shock intensity. Should the parallel between shock intensity and reinforcement magnitude hold, relative behavior measures would be sensitive to relative shock intensity (see Catania, 1963; Dunn, 1982; Keller & Gollub, 1977; Schneider, 1973; Todorov, 1973; Todorov, Hanna, & Bittencourt de Sá, 1984).

The present data raise a point concerning the ethical treatment of animals. Additional experiments would be required for a categorical assertion about the all-or-none effect of shock intensity on avoidance responding; however, the present results suggest that in research on aversive control there is little to be gained from using shock intensities above the value of approximately 1.2 mA.

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